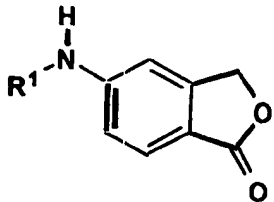
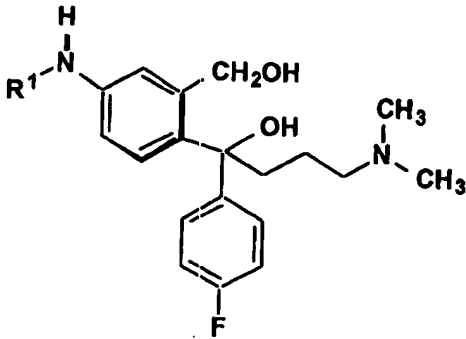




INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification : Not classified	A2	(11) International Publication Number: WO 98/19512 (43) International Publication Date: 14 May 1998 (14.05.98)
(21) International Application Number: PCT/DK97/00513 (22) International Filing Date: 11 November 1997 (11.11.97) (71) Applicant (for all designated States except US): H. LUNDBECK A/S [DK/DK]; Ottiliavej 9, DK-2500 Valby-Copenhagen (DK). (72) Inventors; and (75) Inventors/Applicants (for US only): PETERSEN, Hans [DK/DK]; Guldagervej 11, DK-2720 Vanløse (DK). BREGNEDAL, Peter [DK/DK]; Gærdesmuttevej 1B, DK-3450 Allerød (DK). BØGESØ, Klaus, Peter [DK/DK]; Hørsholm Park 16, 2TV, DK-2970 Hørsholm (DK). (74) Common Representative: H. LUNDBECK A/S; John Meidahl Petersen, Ottiliavej 9, DK-2500 Valby-Copenhagen (DK).		(81) Designated States: AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GE, GH, HU, ID, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZW, ARIPO patent (GH, KE, LS, MW, SD, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG). Published <i>Before the expiration of the time limit referred to in Article 21(2)(a) on the request of the applicant.</i> <i>Without international search report and to be republished upon receipt of that report.</i> <i>Without classification; title and abstract not checked by the International Searching Authority.</i>
(54) Title: METHOD FOR THE PREPARATION OF CITALOPRAM (57) Abstract <p>A method for the preparation of citalopram is described comprising reaction of a compound of Formula (IV) wherein R¹ is H or C₁₋₆alkylcarbonyl successively with a Grignard reagent of 4-halogen-fluorophenyl and a Grignard reagent of 3-halogen-N,N-dimethylpropylamine, effecting ring closure of the resulting compound of Formula (VI) and converting the resulting 1,3-dihydroisobenzofuran compound to the corresponding 5-cyano derivative, i.e. citalopram.</p> <div style="display: flex; justify-content: space-around; align-items: center;"> <div style="text-align: center;">  <p>(IV)</p> </div> <div style="text-align: center;">  <p>(VI)</p> </div> </div>		

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AL	Albania	ES	Spain	LS	Lesotho	SI	Slovenia
AM	Armenia	FI	Finland	LT	Lithuania	SK	Slovakia
AT	Austria	FR	France	LU	Luxembourg	SN	Senegal
AU	Australia	GA	Gabon	LV	Latvia	SZ	Swaziland
AZ	Azerbaijan	GB	United Kingdom	MC	Monaco	TD	Chad
BA	Bosnia and Herzegovina	GE	Georgia	MD	Republic of Moldova	TG	Togo
BB	Barbados	GH	Ghana	MG	Madagascar	TJ	Tajikistan
BE	Belgium	GN	Guinea	MK	The former Yugoslav Republic of Macedonia	TM	Turkmenistan
BF	Burkina Faso	GR	Greece			TR	Turkey
BG	Bulgaria	HU	Hungary	ML	Mali	TT	Trinidad and Tobago
BJ	Benin	IE	Ireland	MN	Mongolia	UA	Ukraine
BR	Brazil	IL	Israel	MR	Mauritania	UG	Uganda
BY	Belarus	IS	Iceland	MW	Malawi	US	United States of America
CA	Canada	IT	Italy	MX	Mexico	UZ	Uzbekistan
CF	Central African Republic	JP	Japan	NE	Niger	VN	Viet Nam
CG	Congo	KE	Kenya	NL	Netherlands	YU	Yugoslavia
CH	Switzerland	KG	Kyrgyzstan	NO	Norway	ZW	Zimbabwe
CI	Côte d'Ivoire	KP	Democratic People's Republic of Korea	NZ	New Zealand		
CM	Cameroon			PL	Poland		
CN	China	KR	Republic of Korea	PT	Portugal		
CU	Cuba	KZ	Kazakstan	RO	Romania		
CZ	Czech Republic	LC	Saint Lucia	RU	Russian Federation		
DE	Germany	LI	Liechtenstein	SD	Sudan		
DK	Denmark	LK	Sri Lanka	SE	Sweden		
EE	Estonia	LR	Liberia	SG	Singapore		

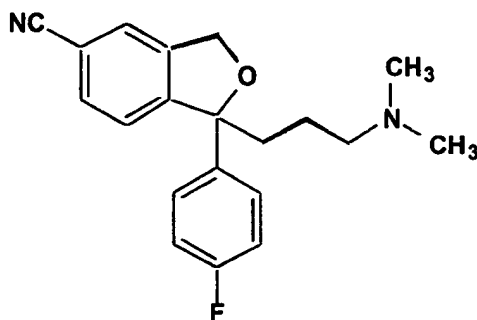
Method for the Preparation of Citalopram

The present invention relates to a method for the preparation of the well known antidepressant drug citalopram and intermediates used in the process.

5

Background of the Invention.

Citalopram is a well known antidepressant drug that has now been on the market for some years and has the following structure:



Formula I

10

It is a selective, centrally active serotonin (5-hydroxytryptamine; 5-HT) reuptake inhibitor, accordingly having antidepressant activities. The antidepressant activity of the compound has been reported in several publications, eg. J. Hyttel, *Prog. Neuro-Psychopharmacol. & Biol. Psychiat.*, **1982**, 6, 277-295 and A. Gravem, *Acta Psychiatr. Scand.*, **1987**, 75, 478-486. The compound has further been disclosed to show effects in the treatment of dementia and cerebrovascular disorders, EP-A 474580.

15

Citalopram was first disclosed in DE 2,657,271 corresponding to US 4,136,193. This patent publication describes the preparation of citalopram by one method and outlines a further method which may be used for preparing citalopram.

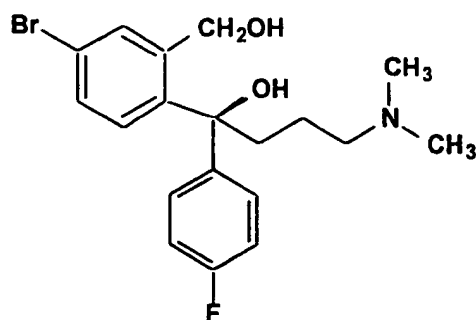
20

According to the process described, the corresponding 1-(4-fluorophenyl)-1,3-dihydro-5-isobenzofurancarbonitrile is reacted with 3-(N,N-dimethylamino)propyl-chloride in the presence of methylsulfinylmethide as condensing agent. The starting material was prepared from the corresponding 5-bromo derivative by reaction with cuprous cyanide.

25

According to the method, which is only outlined in general terms, citalopram may be obtained by ring closure of the compound:

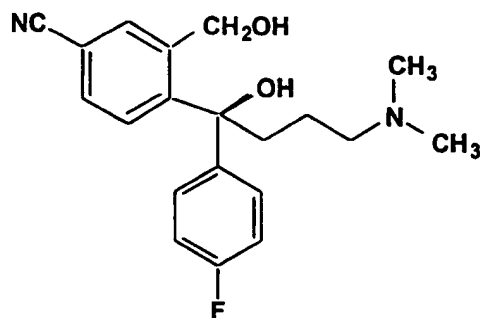
2



Formula II

in the presence of a dehydrating agent and subsequent exchange of the 5-bromo group with cuprous cyanide. The starting material of Formula II is obtained from 5-bromophthalide by two successive Grignard reactions, i.e. with 4-fluorophenyl magnesium chloride and N,N-dimethylaminopropyl magnesium chloride, respectively.

A new and surprising method and an intermediate for the preparation of citalopram were described in US Patent No 4,650,884 according to which an intermediate of the formula



Formula III

is subjected to a ring closure reaction by dehydration with strong sulfuric acid in order to obtain citalopram. The intermediate of Formula III was prepared from 5-cyanophthalide by two successive Grignard reactions, i.e. with 4-fluorophenyl magnesium halogenide and N,N-dimethylaminopropyl magnesium halogenide, respectively.

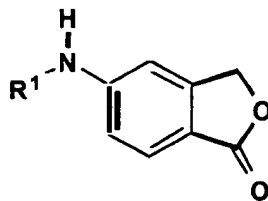
Finally, methods of preparing the individual enantiomers of citalopram are disclosed in US Patent No 4,943,590 from which it also appears that the ring closure of the intermediate of Formula III may be carried out via a labile ester with a base.

It has now, surprisingly, been found that citalopram may be manufactured by a novel favourable and safe procedure using convenient starting materials.

Summary of the invention

Accordingly, the present invention relates to a novel method for the preparation of citalopram comprising the steps of:

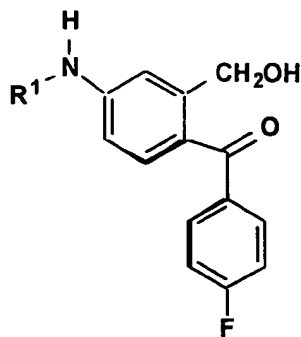
- 5 a) reacting a compound of Formula IV



Formula IV

wherein R¹ is H or C₁₋₆ alkylcarbonyl, with a Grignard reagent of 4-halogen-fluorophenyl;

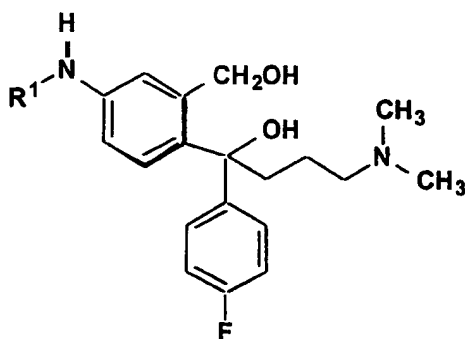
- b) reacting the resulting compound of formula V



Formula V

wherein R¹ is as defined above, with a Grignard reagent of 3-halogen-N,N-dimethylpropylamine;

- c) effecting ring closure of the resulting compound of Formula VI

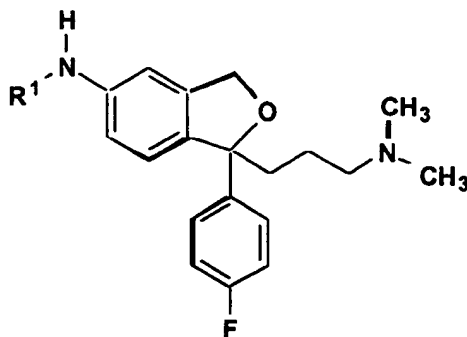


Formula VI

wherein R¹ is as defined above, and

- d) converting the resulting compound of Formula VII

4



Formula VII

wherein R¹ is as defined above, into the corresponding 5-cyano derivative, i.e. citalopram, which is isolated as the base or a pharmaceutically acceptable salt thereof.

5 In another aspect, the present invention provides the novel intermediates of Formula V.

In a further aspect, the present invention provides the novel intermediates of Formula VI.

In a further aspect, the present invention provides the novel intermediates of Formula VII.

10

In yet another aspect, the present invention relates to an antidepressant pharmaceutical composition comprising citalopram manufactured by the process of the invention.

15

Throughout the specification and claims, C₁₋₆ alkyl refers to a branched or unbranched alkyl group having from one to six carbon atoms inclusive, such as methyl, ethyl, 1-propyl, 2-propyl, 1-butyl, 2-butyl, 2-methyl-2-propyl, 2,2-dimethyl-1-ethyl and 2-methyl-1-propyl.

20

Grignard reagents of 4-halogen-fluorophenyl that may be used in step a) are the magnesium halogenides, such as the chloride, bromide or iodide. Preferably the magnesium bromide is used. Grignard reagents of 3-halogen-N,N-dimethylpropylamine that may be used are the magnesium halogenides, such as the chloride, bromide or iodide, preferably the magnesium bromide. Preferably the two reactions are performed successively without isolation of the intermediate.

25

The ring closure of the compound of Formula VI may be effected by an acid or when R¹ is C₁₋₆ alkylcarbonyl, it may alternatively be carried out via a labile ester with a base. Acidic ring closure is performed by an inorganic acid, such as a sulfuric or phosphoric acid, or an organic acid, such as methanesulfonic, p-toluenesulfonic or trifluoroacetic acid. The basic ring closure is performed via a labile ester, such as the methane sulfonyl, p-toluene sulfonyl, 10-camphorsulfonyl, trifluoroacetyl or trifluoromethanesulfonyl ester with addition of a base,

30

such as triethyl amine, dimethylaniline or pyridine. The basic reaction is performed in an

inert solvent, preferably with cooling, in particular about 0 °C and is preferably carried out by a one-pot procedure, i.e. with esterification and simultaneous addition of the base.

When R¹ is H, the conversion of R¹-NH- into cyano is preferably performed by diazotation and followed by reaction with CN⁻. Most preferably NaNO₂ and CuCN and/or NaCN are used. When R¹ is C₁₋₆ alkylcarbonyl, it is initially subjected to hydrolysis thereby obtaining the corresponding compound wherein R¹ is H which is then converted as described above. The hydrolysis may be performed either in acidic or basic environment.

The process of the invention may be carried out with or without isolation of the intermediates.

The process of the invention may also be used to prepare the active (S)-enantiomer of citalopram. In that case, the compound of formula VI is separated into the optically active enantiomers by a procedure analogous to the one described in US Patent No 4,943,590 thereby obtaining the (S)-enantiomer of the compound of formula VI which is used in the ring closure reaction in step c). Accordingly, the individual enantiomers of the intermediates of formulas VI and VII, respectively, are embraced by the formulas.

Other reaction conditions, solvents, etc. are conventional conditions for such reactions and may easily be determined by a person skilled in the art.

The starting material of formula IV wherein R¹ is H is commercially available and may be prepared by known procedures (Tirouflet, J.; Bull. Soc. Sci. Bretagne 26, 1959, 35) and compounds wherein R¹ is acyl may be prepared from the amino compound (R¹ is H) by conventional acylation.

In one embodiment of the invention, R¹ is C₁₋₆ alkylcarbonyl, in particular methyl-, ethyl-, propyl-, or butylcarbonyl.

30

In another embodiment of the invention R¹ is H.

The compound of general Formula I may be used as the free base or as a pharmacologically acceptable acid addition salt thereof. As acid addition salts, such salts formed with organic or inorganic acids may be used. Exemplary of such organic salts are those with maleic, fumaric, benzoic, ascorbic, succinic, oxalic, bis-methylenesalicylic, methanesulfonic, ethanedisulfonic, acetic, propionic, tartaric, salicylic, citric, gluconic, lactic, malic, mandelic, cinnamic, citraconic, aspartic, stearic, palmitic, itaconic, glycolic, p-amino-benzoic, glutamic,

35

benzene sulfonic and theophylline acetic acids, as well as the 8-halothephyllines, for example 8-bromothephylline. Exemplary of such inorganic salts are those with hydrochloric, hydrobromic, sulfuric, sulfamic, phosphoric and nitric acids.

- 5 The acid addition salts of the compounds may be prepared by methods known in the art. The base is reacted with either the calculated amount of acid in a water miscible solvent, such as acetone or ethanol, with subsequent isolation of the salt by concentration and cooling, or with an excess of the acid in a water immiscible solvent, such as ethylether, ethylacetate or dichloromethane, with the salt separating spontaneously.

10

The pharmaceutical compositions according to the invention may be administered in any suitable way and in any suitable form, for example orally in the form of tablets, capsules, powders or syrups, or parenterally in the form of usual sterile solutions for injection.

- 15 The pharmaceutical formulations of the invention may be prepared by conventional methods in the art. For example, tablets may be prepared by mixing the active ingredient with ordinary adjuvants and/or diluents and subsequently compressing the mixture in a conventional tableting machine. Examples of adjuvants or diluents comprise: Corn starch, potato starch, talcum, magnesium stearate, gelatine, lactose, gums, and the like. Any other adjuvant or
20 additive colourings, aroma, preservatives etc. may be used provided that they are compatible with the active ingredients.

- Solutions for injections may be prepared by solving the active ingredient and possible additives in a part of the solvent for injection, preferably sterile water, adjusting the solution
25 to the desired volume, sterilization of the solution and filling in suitable ampules or vials. Any suitable additive conventionally used in the art may be added, such as tonicity agents, preservatives, antioxidants, etc.

Examples

30

The process of the invention is further illustrated by the following Examples.

Example 1

4-Dimethylamino-1-(4-amino-2-hydroxymethylphenyl)-1-(4-fluorophenyl)butan-1-ol.

- 35 A solution of 4-fluorophenylmagnesium bromide prepared from 4-fluorobromobenzene (116 g, 0.66 mole) and magnesium turnings (20 g, 0.8 mole) in dry THF (500 ml), is added dropwise to a suspension of 5-amino-phthalide (30 g, 0.2 mole) in dry THF (500 ml). The

temperature is kept below 5 °C. After the addition is completed, the reaction mixture is stirred for 0.5 hour at room temperature.

A second Grignard solution prepared from 3-dimethylaminopropyl chloride (25 g, 0.2 mole) and magnesium turnings (6 g, 0.25 mole) in dry THF (150 ml) is added to the reaction mixture. The temperature is kept below 5°C during the addition. Stirring is continued for 0.5 hour, then stopped and left overnight at ambient temperature.

The reaction mixture is broken with ice water (1000 ml) and acetic acid (60 g). THF is evaporated off *in vacuo*. The aqueous phase is washed with ethyl acetate (2x200 ml). To the aqueous phase is added NH₄OH to give a final pH of 9. The aqueous layer is extracted with ethyl acetate (2x200 ml), and the organic phase is filtered and washed with water (100 ml). Evaporation of the solvents *in vacuo* leaves the title compound (38.8 g, 58 %) as an oil. ¹H NMR (CDCl₃, 500 MHz): 1.45-1.55 (1H, m), 1.65-1.75 (1H, m), 2.2 (6 H, s), 2.27 (1H, m), 2.33 (2H, m), 2.43 (1H, m) 3.6-3.7 (2H, NH₂), 3.97 (1H, d J=12.5Hz) 4.25 (1H, J=12.5Hz), 6.58 (1H, d, J=8Hz), 6.62 (1H, s), 6.95 (2H, t, J=8.5 Hz), 7.25 (1H, d, J=8 Hz), 7.45 (2H, dt, J=1.2 Hz J=8.5 Hz).

5-Amino-1-(3-dimethylaminopropyl)-1-(4-fluorophenyl)-1,3-dihydroisobenzofuran.

Crude 4-dimethylamino-1-(4-amino-2-hydroxymethylphenyl)-1-(4-fluorophenyl)butan-1-ol. is dissolved in H₃PO₄ (60%, 140 g) and heated to 80°C for 2 hours. The reaction mixture is poured on ice water (1000 ml). NH₄OH is added to give a final pH of 9. The aqueous layer is extracted with ethyl acetate (2x200 ml). The combined organic phase is filtered, washed with water (100 ml) and dried (MgSO₄, 10 g). The solvent is evaporated *in vacuo*. The title compound is obtained as an oil.

¹H NMR (CDCl₃, 250 MHz): 1.3-1.5 (2H, m), 2.05-2.3 (10 H, s+m), 3.6-3.7 (2H, NH₂), 5.0 (1H, s), 6.45 (1H, d, J=1.8Hz), 6.55 (1H, dd, J=8 Hz J=1.8 Hz), 6.95 (2H, t, J=8.5 Hz), 7.05 (1H, d, J=8 Hz), 7.45 (2H, dt, J=1.2 Hz J=8.5 Hz).

1-(3-Dimethylaminopropyl)-1-(4-fluorophenyl)-1,3-dihydroisobenzofuran-5-carbonitrile.

5-Amino-1-(3-dimethylaminopropyl)-1-(4-fluorophenyl)-1,3-dihydroisobenzofuran (18 g, 0.06 mole) is dissolved in water (100 ml) and H₂SO₄ (8 ml). NaNO₂ (4.1 g, 0.06 mole) is dissolved in water (20 ml) and added dropwise below 5°C. The diazotised solution is stirred for 0.5 hour at 0-5°C. pH is brought to 6.5 by adding a saturated solution of Na₂CO₃. This solution is added to a mixture of water (100 ml) and toluene (120 ml) containing CuCN (6 g, 0.067 mole) and NaCN (10 g, 0.2 mole) at 50-60 C°. Stirring is continued for 0.5 hour. The phases are separated and the aqueous phase is further extracted with toluene (100 ml). The combined organic phase is washed with NaCN (10% aq., 2x50 ml). The solvent is removed *in vacuo* and the residue is chromatographed on silica gel (ethyl acetate: n-heptane: triethylamine; 85:10:5) to give the title compound (6 g, 32%) as an oil.

¹H NMR (CDCl₃, 250 MHz): 1.35 (1H, m), 1.45 (1 H, m), 2.1 (6H, s), 2.15-2.25 (4H, m), 5.12 (1H, d, J=12.5 Hz), 5.18 (1H, d, J=12.5 Hz), 7.00 (2H, t, J=8.5 Hz), 7.4 (2H, t, J=8.5 Hz), 7.45 (1H, d, J=7.5 Hz), 7.5 (1H, s), 7.58 (1H, d, J=7.5 Hz).

5 Example 2

4-Dimethylamino-1-(4-acetylamino-2-hydroxymethylphenyl)-1-(4-fluorophenyl)butan-1-ol.

A solution of 4-fluorophenylmagnesium bromide prepared from 4-fluorobromobenzene (11.6 g, 0.067 mole) and magnesium turnings (2 g, 0.08 mole) in dry THF (50 ml), is added dropwise to a suspension of 5-acetylamino-phthalide (5 g, 0.03 mole) in dry THF (50 ml).

10 The temperature is kept below 5 °C. After the addition is completed, the reaction mixture is stirred for 0.5 hour at room temperature.

A second Grignard solution prepared from 3-dimethylaminopropyl chloride (3.7 g, 0.03 mole) and magnesium turnings (0.87 g, 0.036 mole) in dry THF (15 ml) is added to the reaction mixture. The temperature is kept below 5°C during the addition. Stirring is

15 continued for 0.5 hour, then stopped and left overnight at ambient temperature.

The reaction mixture is broken with ice water (100 ml) and acetic acid (6 g). THF is evaporated off *in vacuo*. The aqueous phase is washed with ethyl acetate (2x50 ml). To the aqueous phase is added NH₄OH to give a final pH of 9. The aqueous layer is extracted with ethyl acetate (2x50 ml), and the organic phase is filtered and washed with water (50 ml).

20 Evaporation of the solvents *in vacuo* leaves the title compound (6.6 g, 63 %) as an oil.

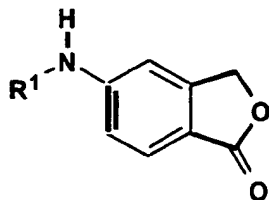
¹H NMR (DMSO-d₆, 500 MHz): 1.15-1.22 (1H, m), 1.40-1.50 (1H, m), 2.02 (9 H, s+s), 2.05 (1H, m), 2.13 (2H, m), 2.20 (1H, m), 3.95 (1H, d J=12.5Hz) 4.48 (1H, d J=12.5Hz), 7.05 (2H, t, J=8.5Hz), 7.14 (2H, dd J=8.5Hz J= 1.2Hz), 7.47 (1H, d J=8 Hz), 7.58 (1H, s), 7.64 (1H, d J=8.5 Hz).

25

CLAIMS

1. A method for the preparation of citalopram comprising the steps of

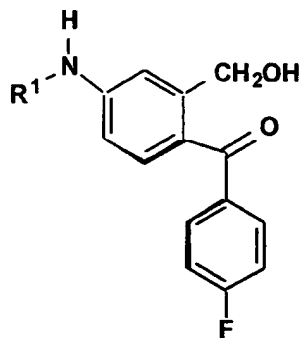
a) reacting a compound of Formula IV



Formula IV

wherein R¹ is H or C₁₋₆ alkylcarbonyl with a Grignard reagent of 4-halogen-fluorophenyl;

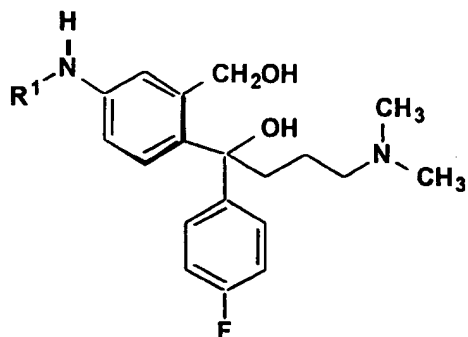
b) reacting the resulting compound of formula V



Formula V

wherein R¹ is as defined above, with a Grignard reagent of 3-halogen-N,N-dimethylpropyl-amine;

c) effecting ring closure of the resulting compound of Formula VI

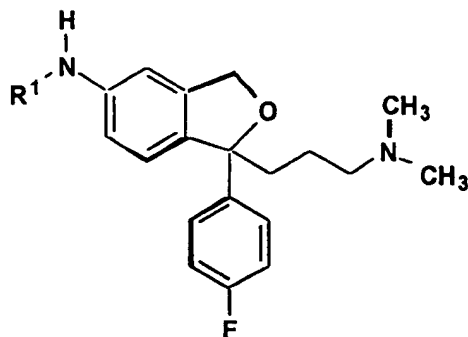


Formula VI

wherein R¹ is as defined above, and

d) converting the resulting compound of Formula VII

10

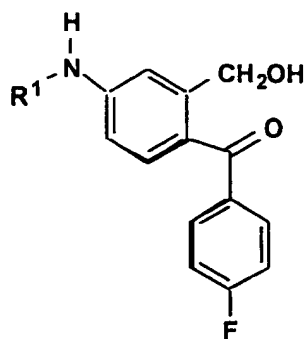


Formula VII

wherein R¹ is as defined above, into the corresponding 5-cyano derivative, i.e. citalopram, which is isolated as the base or a pharmaceutically acceptable salt thereof.

- 5 2. The method of Claim 1 wherein R¹ is H.
3. The method of Claim 1 wherein R¹ is C₁₋₆ alkylcarbonyl
4. The method of Claim 3 wherein C₁₋₆ alkyl is methyl, ethyl, propyl, or butyl.
- 10 5. The method of Claim 1-4 wherein the Grignard reagent used are magnesium halogenides, preferably the chlorides, bromides or iodides.
6. The method of Claim 5 wherein the Grignard reagents used in step a) is the magnesium
- 15 bromide.
7. The method of Claim 5 wherein the Grignard reagents used in step b) is the magnesium chloride.
- 20 8. The method of any of Claims 1-7 wherein the ring closure of the compound of Formula VI is effected by acidic ring closure performed by an inorganic acid, such as a sulfuric or phosphoric acid, or an organic acid, such as methanesulfonic, p-toluenesulfonic or trifluoroacetic acid.
- 25 9. The method of Claim 3 wherein the ring closure of the compound of Formula VI is performed by a basic ring closure via a labile ester, preferably with simultaneous esterification and addition of base.
- 30 10. The method of Claim 9 wherein the labile ester is the methane sulfonyl, p-toluene sulfonyl, 10-camphorsulfonyl, trifluoroacetyl or trifluoromethanesulfonyl ester and the base is triethyl amine, dimethylaniline or pyridine.

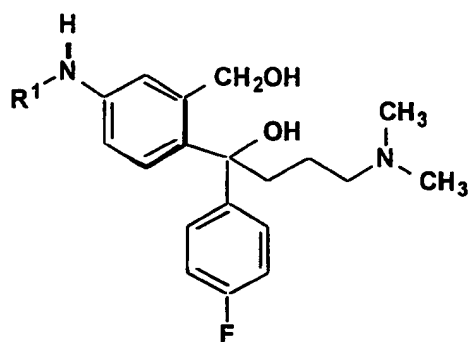
11. The method of Claim 2 wherein the conversion of the group R^1-NH- into cyano is performed by diazotation followed by reaction with CN^- .
- 5 12. The method of Claim 3 wherein the conversion of the group R^1-NH- to cyano is performed by hydrolysis of the C_{1-6} alkylcarbonyl amino group, R^1-NH- , to the corresponding amino group wherein R^1 is H, followed by diazotation and reaction with CN^- .
- 10 13. A process of any of Claims 1 - 12 characterised in that before it is used in the ring closure reaction in step c), the compound of formula VI is separated into the optically active enantiomers thereby obtaining the (S)-enantiomer.
14. A compound of Formula V



Formula V

15 wherein R^1 is H or C_{1-6} alkylcarbonyl.

15. A compound of Formula VI



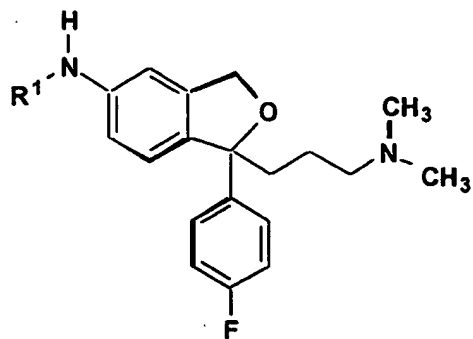
Formula VI

wherein R^1 is H or C_{1-6} alkylcarbonyl.

20

16. A compound of Formula VII

12



Formula VII

wherein R^1 is H or C_{1-6} alkylcarbonyl.

17. An antidepressant pharmaceutical composition comprising citalopram manufactured by
5 the process of any of Claims 1 - 13.